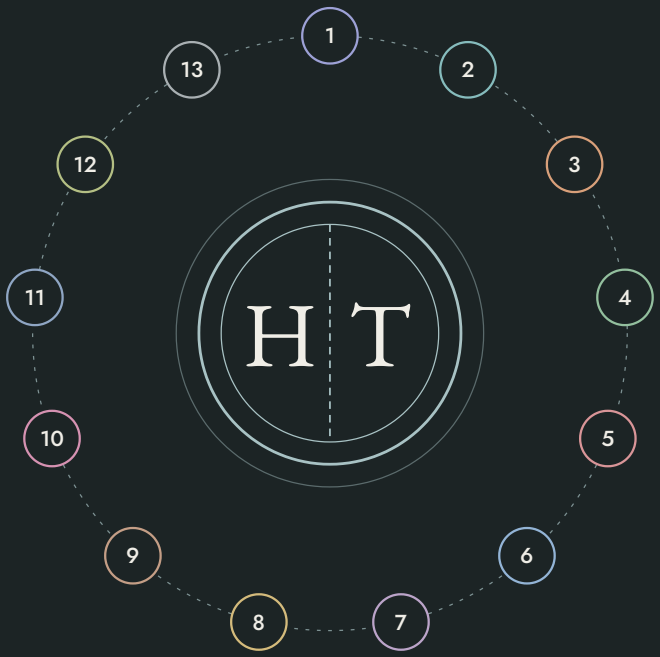
The Quantum Coin Puzzle

13 families of answers to
the quantum measurement puzzle



This booklet doesn't pick a winner.

You can explore them all.

LET'S BEGIN

The case of the curious coin

Meet our pretend **quantum coin**. Quantum theory's usual equations allow a thing to be in several states at once. For the coin, that means the maths can say 'heads and tails together'.

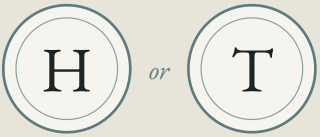
What the equations allow



several states at once:
'heads and tails together'

yet...

What we find when we look



always one definite result:
heads, or tails

Yet when we look, we always find **one** definite result: heads, or tails. It is like a pointer that points one way, not both.



This is the measurement problem

How does that one definite result appear? And what is the **wavefunction** (the theory's mathematical description) saying about the world?

? **Hold that thought.** Is 'heads and tails together' a real blur out there in nature, or only a tool for predictions and advice? That is the first of the four big questions on page 4.

The coin is only make-believe. It is this booklet's way of picturing a thing in several states at once, which the booklet calls a **superposition**. Tricky words are gathered in the word bank on page 23.

So what is everybody debating?



the wavefunction says 'heads and tails together'

The wavefunction

Quantum theory's mathematical description, also called the **quantum state**. For our coin, it is the maths that says 'heads and tails together'.

An interpretation

A worked-out answer to the measurement problem. It says:

1. **what is real**
2. **how the state changes**
3. **how a definite result (or something in its place) shows up**

A price

Every family buys its solution by accepting a difficulty. The guide calls that **the price it pays**.

1 2 3 4 5 6 7 8 9 10 11 12 13

The 13 **families** of interpretations in this booklet come from the *Quantum Ontology Map*, by way of its *Plain-Language Guide*. That guide is this booklet's only source.

No winner is marked

The guide marks no preferred stance, and neither does this booklet. Most of the families cannot be told apart from ordinary quantum theory by experiment (see page 8). The map organises the families with a set of questions. Turn the page for four of them!

Four big questions

The map organises every family with a set of questions. These four place a family as an answer to the measurement problem. Their icons are on every family page, and page 20 explains the short answers beside them.

Is the wavefunction real?

Is it a real feature of the world, or only a tool for predictions and advice? If it is real, the blur of possibilities is out there in nature. If it is only a tool, the puzzle shifts to what, if anything, sits behind the tool.

Does it always follow the smooth law?

Does the wavefunction always change in the ordinary smooth way, or is that law changed or replaced? The ordinary law, called **unitary evolution**, is a smooth, reversible change that never picks a single result by itself. It is extremely well tested, so changing it is a big step. Leaving it alone means the definite result must come from somewhere else.

How does a definite result show up?

This is the heart of the measurement problem. Does every possibility happen in some branch? Does extra hidden stuff pick one result? Does the state itself collapse? Or is only advice or information updated? (The guide's chart has a fifth label too, for ensemble views: see page 14.)

What price does it pay?

Every family buys its solution by accepting a difficulty: such as many worlds and a puzzle about probability, instant influence at a distance, new numbers to test, or a weaker idea of a single shared world.



Word to know: entanglement. Quantum systems can be tied together so tightly that they share a state. That shared state is called entanglement. It is not just a list of separate states.

Bonus questions for deep thinkers

The map asks three more. They are optional deeper readings: they are not forced by the quantum equations.

- Where does the basic physical stuff live? Some views put the real state in **configuration space** (a vast space of all possible arrangements). Some put matter in ordinary three-dimensional space or in spacetime. Some treat regions of spacetime themselves as carrying the state.
- Are relations or structure more basic than objects?
- Is the universe as a whole, or ongoing process, more basic than its parts?

Follow them up on page 22.

THE LINE-UP

Meet the 13 families

One page each, in the same order as the guide. Dip in anywhere you like!

		Wavefunction real?	
1	**Many worlds** Spelt out: comparatively well	Yes	p. 6
2	**Pilot-wave** Spelt out: comparatively well	Yes	p. 7
3	**Objective collapse** Spelt out: comparatively well	Yes	p. 8
4	**Modal interpretations** Spelt out: comparatively well, despite well-known gaps	Yes	p. 9
5	**Relational quantum mechanics** Spelt out: comparatively well	No	p. 10
6	**QBism** Spelt out: comparatively well	No	p. 11
7	**Copenhagen and pragmatist views** Spelt out: comparatively well	No	p. 12
8	**Consistent histories** Spelt out: comparatively well	No	p. 13
9	**Ensemble views** Spelt out: comparatively well, but incomplete for a single run on its own	No	p. 14
10	**Retrocausal views** Spelt out: unevenly; a recognised family with no agreed completion	Depends	p. 15
11	**Gravity-related collapse** Spelt out: still exploratory, without comparably settled workings	Yes	p. 16
12	**Consciousness-involving collapse** Spelt out: still exploratory, without comparably settled workings	Yes	p. 17
13	**Superdeterminism** Spelt out: still exploratory, without comparably settled workings	No	p. 18

How to read the line-up

Wavefunction real? Question 1 from page 4, with the guide's own answers. Page 20 says more about them.

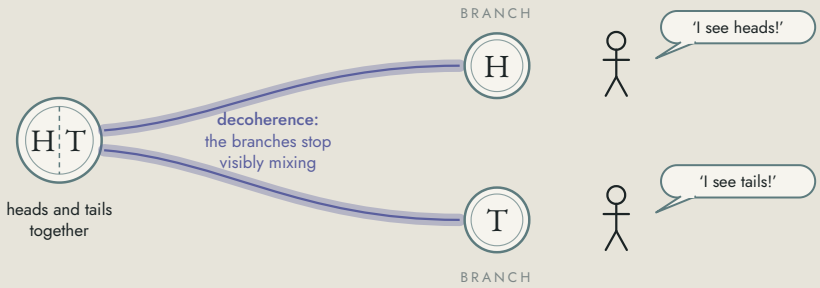
Spelt out. The guide says the workings of the first nine families (its word is 'dynamics'), and their accounts of what exists, are comparatively well specified. For the other four, it says the specification is uneven, or the programme is still exploratory. **This is not a ranking of which view is true.**

And remember: each family page tells you what that family *says*. Saying it doesn't make it so.

FAMILY 1 OF 13

1 *Many worlds*

Formal name: Everett / Many-Worlds
Spelt out: comparatively well



ⓘ **Our coin:** Heads and tails both happen, each in its own branch. Observers branch too.

THE BIG IDEA

The wavefunction of the whole universe is real and never collapses. Every outcome happens in a branch that has become effectively separate.

Wavefunction real?	Always the smooth law?	How a definite result shows up
Yes	Yes	**All happen, in branches**

KEY FEATURES

1. There is one real quantum state for the whole universe, and it always follows the ordinary smooth law.
2. Every possible result occurs, each in its own **branch**. The branches stop visibly mixing (a process called **decoherence**) and become the familiar worlds. Those worlds are patterns in the state, not extra fundamental stuff added on top.
3. **Observers** are ordinary physical systems that branch too. They play no special role in the law.
4. In all tested cases it matches ordinary quantum theory. The disputed centrepiece is how probability still makes sense, and what exactly a world is.

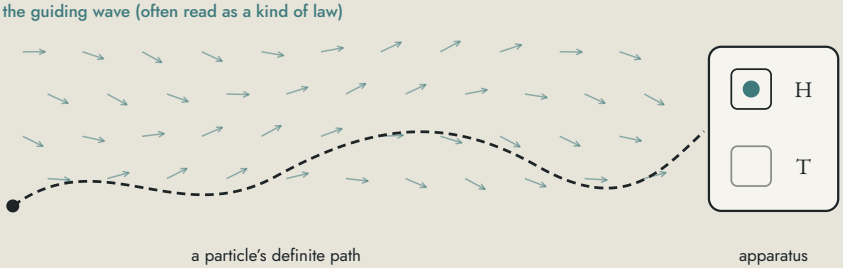
THE PRICE IT PAYS

Making sense of probability when every outcome happens, and saying what exactly a 'world' is.

FAMILY 2 OF 13

2 *Pilot-wave*

Formal name: Bohmian Mechanics (Pilot-Wave)
Spelt out: comparatively well



ⓘ **Our coin:** There is always one actual result: heads, or tails. It is fixed by where the particles in the apparatus are.

THE BIG IDEA

Particles have definite paths in ordinary space, guided by a wave that follows the ordinary smooth law. So there is always one actual result.

Wavefunction real?	Always the smooth law?	How a definite result shows up
Yes	Yes	**Extra variables**

KEY FEATURES

1. Particles always have definite positions and paths in ordinary three-dimensional space.
2. A wavefunction for the whole universe guides those particles. The wave itself follows the ordinary smooth law, and is often read as a kind of law rather than as a second kind of stuff.
3. There is always one actual result, fixed by where the particles in the apparatus are.
4. In the usual equilibrium it matches ordinary quantum statistics. The cost is instant influence across entangled systems.

THE PRICE IT PAYS

Dynamical **nonlocality**: each particle's velocity can depend at once on the positions of distant entangled partners. Standard versions also need a preferred slicing of time.

FAMILY 3 OF 13

3 *Objective collapse*

Formal name: Objective Collapse (GRW / CSL)
Spelt out: comparatively well



ⓘ **Our coin:** A tiny coin's 'heads and tails together' would almost never collapse. A large one would collapse quickly to one result.

THE BIG IDEA

The wavefunction is real, but the law is changed so that it spontaneously collapses to one result, faster as objects get larger.

Wavefunction real?	Always the smooth law?	How a definite result shows up
Yes	No (law changed)	**Physical collapse**

KEY FEATURES

1. The quantum state is real. Some versions add flashes in spacetime or a matter density in ordinary space. A bare version treats the wavefunction itself as the stuff.
2. The ordinary smooth law is modified by a random, physical **collapse**. Large superpositions collapse quickly; tiny ones almost never do.
3. A single definite result is produced by the physics, with no special role for observers.
4. Unlike most other families, this one could in principle be told apart from ordinary quantum theory by experiment, because it changes the law.

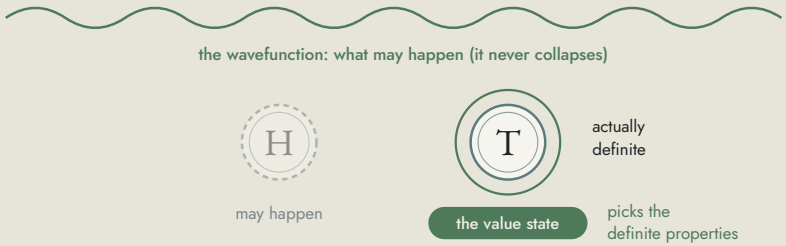
THE PRICE IT PAYS

New numbers in the collapse law that experiments can test, plus nonlocal collapse across entangled systems.

FAMILY 4 OF 13

4 *Modal interpretations*

Formal name: Modal Interpretations
Spelt out: comparatively well, despite well-known gaps



ⓘ **Our coin:** The wavefunction says that heads and tails may happen. The value state picks which is actually definite.

THE BIG IDEA

The wavefunction says what may happen and never collapses. An extra **value state** picks the definite properties in the one actual world.

Wavefunction real?	Always the smooth law?	How a definite result shows up
Yes	Yes	**Extra variables**

KEY FEATURES

1. The state has two parts: a wavefunction that follows the ordinary smooth law, and a value state that selects which properties are actually definite.
2. A single definite result appears without collapse, by this selection of actual properties.
3. Observers have no privileged role. The properties of the apparatus become definite by the same rule.
4. The view aims to match ordinary quantum theory, but faces well-known technical objections about slightly imperfect detectors and about measurements made one after another.

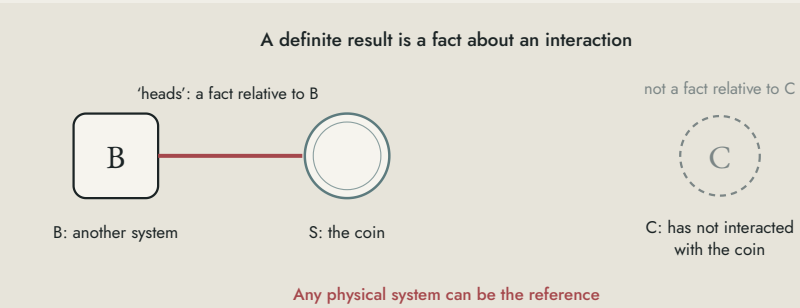
THE PRICE IT PAYS

Nonlocality and tension with relativity, plus technical objections about imperfect measurements and the lack of feedback from the actual result to the evolving wavefunction.

FAMILY 5 OF 13

5 *Relational quantum mechanics*

Formal name: Relational Quantum Mechanics (RQM)
Spelt out: comparatively well



ⓘ **Our coin:** 'Heads' is a fact about an interaction. It is real only relative to the system the coin interacts with.

THE BIG IDEA

Facts about a system's properties are real only relative to another system it interacts with. In the original version there is no single absolute list of events.

Wavefunction real?	Always the smooth law?	How a definite result shows up
No	No (reassigned)	**Relative to a system**

KEY FEATURES

1. The wavefunction is bookkeeping for predictions, not a universal physical field. Supporters treat this as realism about relative facts, not as a mere instrument for predictions.
2. A definite result is a fact about an interaction between physical systems. No consciousness is required. Any physical system can be the reference, which is a sharp contrast with QBism.
3. Versions differ on whether events themselves are absolute. The original version denies a perspective-independent list of events. A later version adds links between perspectives and a sparse network of observer-independent events, while states remain relational.
4. It is built to match ordinary quantum theory. Whether it dissolves or only relocates the puzzle of influence at a distance is disputed.

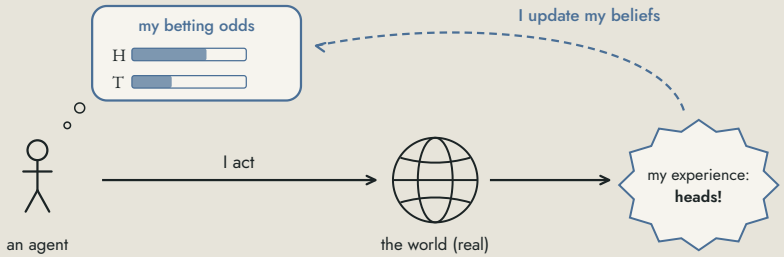
THE PRICE IT PAYS

A weaker idea of a single shared world: critics press the problem of agreement between different perspectives.

FAMILY 6 OF 13

6 *QBism*

Formal name: QBism
Spelt out: comparatively well



ⓘ **Our coin:** The wavefunction's 'heads and tails together' is never a physical field. It records an agent's betting odds on what they will experience.

THE BIG IDEA

The world is real, but the wavefunction is an agent's personal degrees of belief, updated when that agent acts and experiences an outcome.

Wavefunction real?	Always the smooth law?	How a definite result shows up
No	No (reassigned)	**Update of advice**

KEY FEATURES

1. A real external world exists, but the wavefunction is never a physical field. It records a person's betting odds on what they will experience.
2. There is no physical collapse. A measurement is an action that generates an outcome for that agent, not passive reading of a pre-existing sample.
3. Unlike relational quantum mechanics, this view needs a decision-making **agent** with beliefs and lived experience.
4. It matches ordinary quantum theory, and treats the standard probability rule as a consistency requirement on those beliefs.

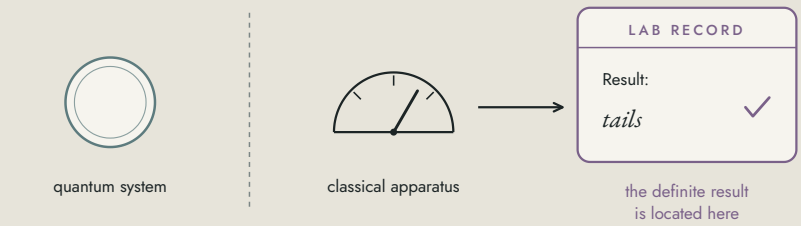
THE PRICE IT PAYS

A weaker idea of a third-person shared world: outcomes are an agent's own experiences.

FAMILY 7 OF 13

7 Copenhagen and pragmatist views

Formal name: Copenhagen, Pragmatist and Operational Cluster
Spelt out: comparatively well



ⓘ **Our coin:** The wavefunction is advice or a predictive tool. The definite result is located in a laboratory record or a stable experimental claim.

THE BIG IDEA

A historically diverse family that treats the wavefunction as advice or a predictive tool, and locates definite results in laboratory records or stable experimental claims.

Wavefunction real?	Always the smooth law?	How a definite result shows up
No	No (reassigned)	**Update of advice**

KEY FEATURES

1. This is a cluster, not one single text. It takes in complementarity and classical experimental contexts; objective advice for agents in particular situations; and information-based reconstructions of the formalism.
2. The wavefunction is not a picture of a physical field. The state is reassigned when the context or the available advice changes. One important pragmatist version says there is no physical collapse.
3. A single objective result is grounded in a classically described experimental record, or in a stable claim after the environment has done its work.
4. It recovers ordinary quantum theory by design. A familiar objection is the shifting split between the quantum system and the classical apparatus.

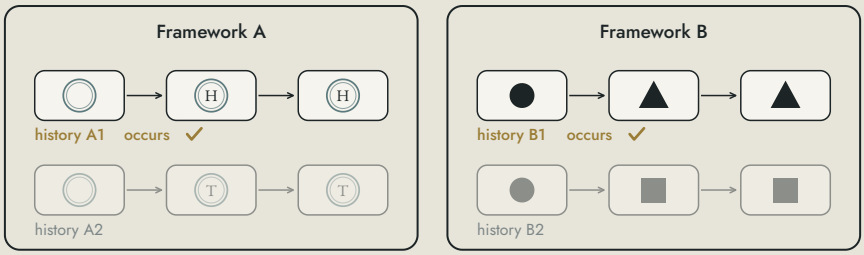
THE PRICE IT PAYS

A weaker idea of a view-from-nowhere description, including a familiar worry about the shifting line between the quantum system and the classical apparatus.

FAMILY 8 OF 13

8 *Consistent histories*

Formal name: Consistent / Decoherent Histories
Spelt out: comparatively well



Within one chosen framework, one history occurs.

ⓘ **Our coin:** Within one chosen framework, one history occurs: for example, one in which the coin comes up heads.

THE BIG IDEA

Quantum events are told as a consistent story, called a **framework**. Within one framework one **history** occurs, but there is no single absolute history independent of that choice.

Wavefunction real?	Always the smooth law?	How a definite result shows up
No	Yes	**Within a framework**

KEY FEATURES

1. The basic objects are time-ordered stories of events, grouped into families that do not interfere with themselves.
2. The fine-grained workings follow the ordinary smooth law. A consistency test picks the families that may be used.
3. Within one chosen framework, one history occurs. Critics treat the lack of a single absolute history as the cost. Supporters stress that, inside a framework, there is still one outcome.
4. The wavefunction is treated as a calculating tool, not as a concrete physical field. The approach is widely used for the universe treated as a closed system.

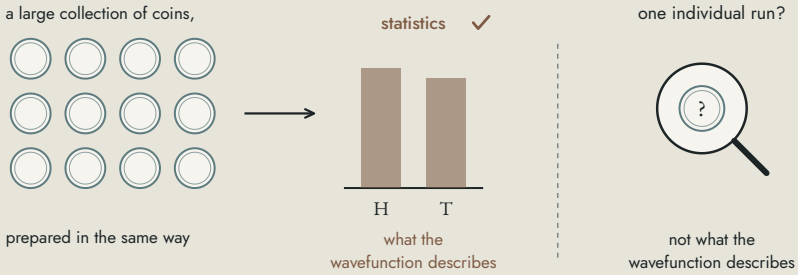
THE PRICE IT PAYS

Framework-relativity: there is no single absolute history independent of the chosen consistent family.

FAMILY 9 OF 13

9 *Ensemble views*

Formal name: Ensemble / Statistical Interpretations
Spelt out: comparatively well, but incomplete for a single run on its own



ⓘ **Our coin:** The wavefunction describes only the statistics of a large collection of coins prepared in the same way, not one individual run.

THE BIG IDEA

The wavefunction describes only the statistics of a large collection of similarly prepared systems, not one individual run.

Wavefunction real?	Always the smooth law?	How a definite result shows up
No	Yes	**Statistics only**

KEY FEATURES

1. The wavefunction is about an **ensemble** (a large collection of systems prepared in the same way), not about the real state of one system.
2. The ensemble's probabilities follow the ordinary smooth law.
3. A single run is left unexplained unless something extra (**hidden variables**) is added.
4. Until those extras are specified, the view takes no position on influence at a distance. Once they are added, well-known theorems tightly constrain what they can be.

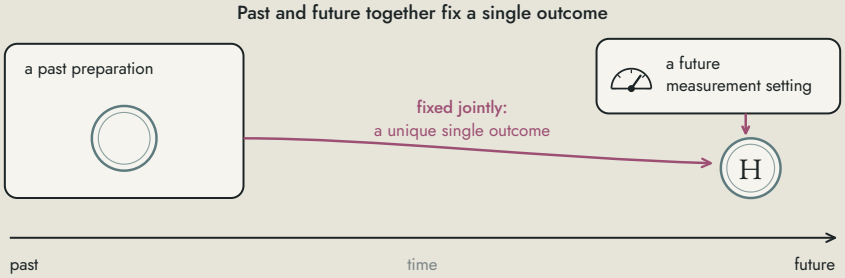
THE PRICE IT PAYS

On its own the view is incomplete for a single case. It needs a hidden-variable completion, at which point tight no-go theorems apply.

FAMILY 10 OF 13

10 *Retrocausal views*

Formal name: Retrocausal and Time-Symmetric Approaches
Spelt out: unevenly; a recognised family with no agreed completion



ⓘ **Our coin:** A past preparation and a future measurement setting together fix the coin's single outcome.

THE BIG IDEA

Past and future **boundary conditions** together fix a single outcome. So what we later choose to measure can be part of what constrains the past.

Wavefunction real?	Always the smooth law?	How a definite result shows up
Depends	No (two-time)	**Extra variables**

KEY FEATURES

1. This is a mixed family, not one single theory. Some versions treat the wavefunction as real. Others treat it as a tool and put the real story in spacetime histories.
2. The workings are time-symmetric, or fixed jointly by a past preparation and a future measurement setting.
3. There is a unique single outcome, fixed across spacetime by those two-time constraints.
4. The aim is to match ordinary quantum theory while avoiding a preferred slicing of time. Complete versions in interacting field theory remain under construction, and none is an agreed completion.

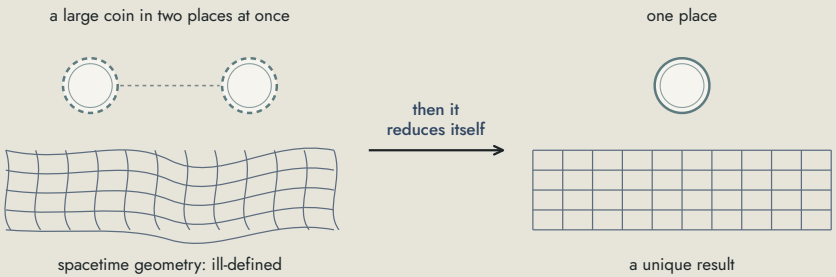
THE PRICE IT PAYS

Retrocausation, or the need for boundary conditions in the future as well as the past.

FAMILY 11 OF 13

11 *Gravity-related collapse*

Formal name: Penrose–Diósi Gravity-Related Collapse
Spelt out: still exploratory, without comparably settled workings



ⓘ **Our coin:** On this page, 'several states at once' means two places at once. A large coin in two places is taken to make spacetime geometry ill-defined, and then to reduce itself.

THE BIG IDEA

A real wavefunction collapses when gravity makes a large superposition in space unstable.

Wavefunction real?	Always the smooth law?	How a definite result shows up
Yes	No (law changed)	**Physical collapse**

KEY FEATURES

1. Large superpositions in space are taken to make spacetime geometry ill-defined, and then to reduce themselves.
2. The proposed mechanism is gravitational objective reduction. There are not yet agreed relativistic workings comparable to the main objective-collapse theories.
3. A unique result comes from this gravity-driven reduction. Observers play no special role in the core proposal.
4. Parts of the programme are testable. Underground radiation tests have ruled out the simplest parameter-free version of one scheme. That radiation prediction comes from that scheme's own workings, not from every version of the proposal.

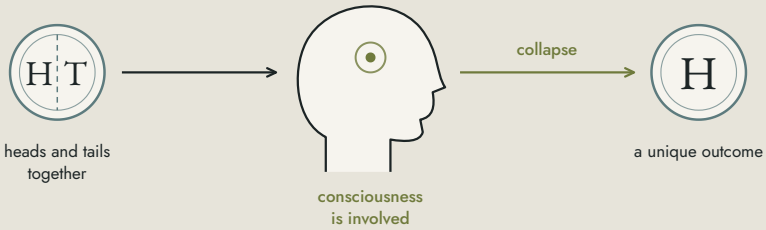
THE PRICE IT PAYS

A new collapse mechanism and nonlocality, without agreed relativistic workings as developed as the main objective-collapse theories. Some simple versions have already been constrained by tests.

FAMILY 12 OF 13

12 *Consciousness-involving collapse*

Formal name: Consciousness-Involving Collapse
Spelt out: still exploratory, without comparably settled workings



ⓘ **Our coin:** The coin's wavefunction is real and physical. A unique outcome is triggered when the superposition involves consciousness.

THE BIG IDEA

A real physical wavefunction collapses when it becomes tied up with consciousness.

Wavefunction real?	Always the smooth law?	How a definite result shows up
Yes	No (law changed)	**Physical collapse**

KEY FEATURES

1. There are physical quantum states plus conscious states, or special mental properties, that resist superposition.
2. The proposed collapse rules remain exploratory. A unique outcome is triggered when a superposition involves consciousness.
3. The observer is essential: conscious mentality is what causes the physical reduction.
4. It faces sharp timing puzzles, including questions about whose consciousness counts.

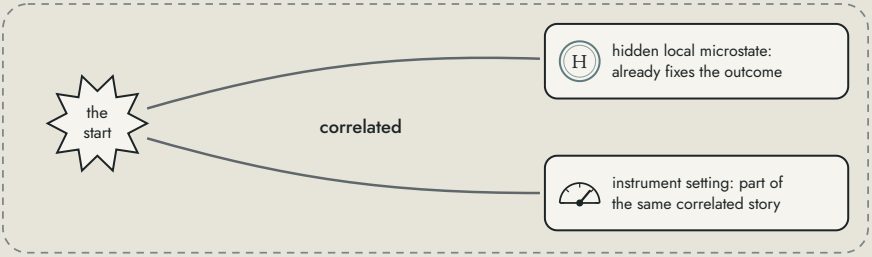
THE PRICE IT PAYS

A new collapse mechanism, plus acute puzzles about whose consciousness matters and when the collapse occurs.

FAMILY 13 OF 13

13 *Superdeterminism*

Formal name: Superdeterminism / Invariant-Set Theory
Spelt out: still exploratory, without comparably settled workings



ⓘ **Our coin:** A single outcome is already fixed by a hidden microstate. The experimenters' choice of setting is part of the same correlated story.

THE BIG IDEA

Hidden local states have been correlated with later instrument settings from the start, or by a global constraint on allowed histories. So a usual independence assumption in **Bell's theorem** does not hold.

Wavefunction real?	Always the smooth law?	How a definite result shows up
No	No (initial)	**Extra variables**

KEY FEATURES

1. Typical versions in this family treat the wavefunction as a tool. The real state is a hidden local **microstate**, such as a cellular-automaton state or a point in a constrained state space.
2. The hidden-level workings are typically deterministic and local. Apparent randomness comes from not knowing the exact microstate.
3. A single outcome is already fixed by that microstate. Experimenters' setting choices are part of the same correlated story, not independent of it.
4. There is no agreed field-theory completion. Cosmic tests have tightened some related loopholes, without settling the programme.

THE PRICE IT PAYS

A very strong constraint on initial conditions or statistical independence. Critics call this implausible fine-tuning; supporters describe it as a law-like or geometric constraint.

So which one is right?

This booklet can't tell you! The guide marks no preferred stance, and neither do we.

All 13 families answer the same puzzle: how a definite result (or something in its place) shows up, and what the wavefunction is saying about the world. Each buys its solution by accepting a difficulty. The guide calls nine of them comparatively well specified (one despite well-known gaps, one though incomplete for a single run on its own), one uneven and three exploratory. It adds that this is not a ranking of which view is true.

Your turn to think

1. Explain it
Can you explain the measurement problem to someone else, in your own words? Use the coin!

2. Chart check
Turn to page 20. Which families answer **Yes** to question 1 ('Wavefunction real?')? Which answer **No**? Which one answers **Depends**?

3. Weigh the cost
Pick two families with different price labels on page 21. Which price seems harder to accept, and why?

4. Draw it
On a spare sheet of paper, draw your own picture of what one family says about the coin.

5. Your question
What would you most like to ask about the puzzle next?

Number 2 has answers you can look up.
For the other four, there is no single right answer.

Over the page: all 13 families side by side, then a bonus page for deep thinkers and the word bank.

How do they answer?

	Family	Wavefunction real?	Always the smooth law?	How a definite result shows up
1	Many worlds	Yes	Yes	All happen, in branches
2	Pilot-wave	Yes	Yes	Extra variables
3	Objective collapse	Yes	No (law changed)	Physical collapse
4	Modal interpretations	Yes	Yes	Extra variables
5	Relational quantum mechanics	No	No (reassigned)	Relative to a system
6	QBism	No	No (reassigned)	Update of advice
7	Copenhagen and pragmatist views	No	No (reassigned)	Update of advice
8	Consistent histories	No	Yes	Within a framework
9	Ensemble views	No	Yes	Statistics only
10	Retrocausal views	Depends	No (two-time)	Extra variables
11	Gravity-related collapse	Yes	No (law changed)	Physical collapse
12	Consciousness-involving collapse	Yes	No (law changed)	Physical collapse
13	Superdeterminism	No	No (initial)	Extra variables

Wavefunction real? The guide's answers to question 1. Its chart note puts the question as 'is the wavefunction a real state, or a law-like one'. **Depends** marks a mixed family: some versions treat the wavefunction as real, others as a tool.

Always the smooth law? The guide splits **No** four ways, 'so that a changed physical law is not confused with a mere update of advice'. See pages 8 (law changed), 12 (reassigned), 15 (two-time) and 18 (initial: there, 'from the start').

How a definite result shows up. The guide's short labels, with two changes. Its one label 'All / relative' is split three ways here: **All happen, in branches**, **Relative to a system** and **Within a framework**. And **Statistics only** stands for 'Ensemble / update'. Compare **Extra variables** with question 3's 'extra hidden stuff picks one result', and **Update of advice** with 'only advice or information is updated'.

The colours only help you spot patterns. None of the colours means 'better' or 'worse'.

What price does each one pay?

The guide gives every family a price twice. The fuller line is in the price box on the family's own page. The short label comes from the guide's chart, and here it is. Families that share a label are grouped together.

Probability / many worlds Page 4: 'many worlds and a puzzle about probability'	1 Many worlds	p. 6
Instant distant influence Page 4: 'instant influence at a distance'	2 Pilot-wave	p. 7
	4 Modal interpretations	p. 9
New parameters; distant influence Page 4: 'new numbers to test'	3 Objective collapse	p. 8
	11 Gravity-related collapse	p. 16
	12 Consciousness-involving collapse	p. 17
Shared world / frameworks Page 4: 'a weaker idea of a single shared world'	5 Relational quantum mechanics	p. 10
	6 QBism	p. 11
	7 Copenhagen and pragmatist views	p. 12
	8 Consistent histories	p. 13
Incomplete for single cases	9 Ensemble views	p. 14
Causes from the future	10 Retrocausal views	p. 15
Strong initial constraints	13 Superdeterminism	p. 18

Spot the patterns!

Which label is shared by the most families? Now look across at page 20: do the families marked 'No (law changed)' share a price label? Then turn to two families that share a label and read their price boxes. How alike are they?

Deep thinker's map

These five follow up page 4's bonus questions. None of them is a theorem of quantum theory, and a family can often be paired with more than one. Take your time!

A **Wavefunction realism.** The universe's quantum state is a concrete physical field living in the vast space of all particle arrangements, not in ordinary three-dimensional space. **A caution:** The familiar world of three-dimensional objects then has to be recovered from that much larger space.

B **Primitive ontology.** Matter is stuff in ordinary three-dimensional space or in spacetime (particles, flashes, or a matter density), while the wavefunction plays a law-like or guiding role. That law-like role itself can be read in more than one way. **A caution:** Which kind of stuff to choose is not settled by experiment, and full versions in interacting field theory remain demanding.

C **Structural realism.** Physical relations or structure come first, either with no objects at all, or only with very thin objects picked out by those relations. **A caution:** Entanglement motivates this reading but does not prove it, and it still has to be paired with an account of definite outcomes.

D **The whole, or process, first.** The cosmos as a whole may be prior to its parts, or events and becoming may be prior to static things. Quantum holism has been offered as common ground; others argue against that inference. **A caution:** This is not deduced from the quantum formalism. Entanglement and the non-separability of systems do not by themselves entail that the whole, or process, comes first. Compatibility with a given family is often optional and contested.

E **Spacetime and field-theory ontology.** This package covers states of local spacetime regions, networks of local quantities in quantum field theory and, separately, conjectures in which spacetime itself emerges. **A caution:** Keep quantum-gravity conjectures distinct from laboratory quantum mechanics.

Family	*A* wavefunction realism	*B* primitive ontology	*C* structural realism	*D* whole, or process, first	*E* spacetime and field theory
1 Many worlds	●	◐*	●	◐	●
2 Pilot-wave	◐	●	◐	◐	◐
3 Objective collapse	●	●	◐	◐	◐
4 Modal interpretations	◐	◐	◐	◐	◐
5 Relational quantum mechanics	×	◐	●	◐	●
6 QBism	×	×	◐	◐	◐
7 Copenhagen and pragmatist views	×	×	◐	◐	◐
8 Consistent histories	×	×	◐	◐	●
9 Ensemble views	×	◐*	◌	◌	◐
10 Retrocausal views	◐	◐	◐	◐	●
11 Gravity-related collapse	◐	◐	◌	◌	●
12 Consciousness-involving collapse	◐	×	×	◌	◌
13 Superdeterminism	×	◐	◌	◐	◐

● natural (standard) ◐ contested: a live option that is disputed × incompatible

◌ open: the sources used for the map do not address this pairing. Open is never a No.

* Many worlds with B: a non-standard version. Ensemble views with B: only if completed, at which point they become a hidden-variable theory.

Words to know

Agent In QBism, a decision-maker with beliefs and lived experience. (pp. 11, 12)

Boundary conditions In retrocausal views, past and future boundary conditions together fix a single outcome. (p. 15)

Branch In the many worlds family, every possible result occurs, each in its own branch. (pp. 4, 6, 20)

Collapse In some families the wavefunction itself collapses to one result. Pages 16 and 17 also use the word 'reduction'. Other families say there is no physical collapse. (pp. 4, 6, 8, 9, 11, 12, 16, 17, 20)

Configuration space A vast space of all possible arrangements. (p. 4)

Decoherence The process in which the branches stop visibly mixing. (p. 6)

Ensemble A large collection of systems prepared in the same way. (pp. 14, 20)

Entanglement A shared state that ties quantum systems together so tightly that it is not just a list of separate states. (pp. 4, 7, 8, 22)

Framework In the consistent histories family, a consistent story. The guide also calls it 'the chosen consistent family'. Within one framework, one history occurs. (pp. 13, 20, 21)

Hidden variables Something extra, added so that a single run is explained. (pp. 14, 22)

History In the consistent histories family, a time-ordered story of events. Pages 15 and 18 use the word too. (pp. 13, 15, 18)

Interpretation A worked-out answer to the measurement problem. (p. 3)

Measurement problem The puzzle of how one definite result appears, and of what the wavefunction is saying about the world. (pp. 2, 3, 4, 19)

Microstate In superdeterminism, the hidden local state that already fixes a single outcome. (p. 18)

Nonlocality Where a family page says nonlocality, the guide's chart says 'instant distant influence' or 'distant influence'. (pp. 7, 8, 9, 16)

Observer The guide does not say what counts as one. On page 6, observers are ordinary physical systems. On page 17, the observer is essential. (pp. 6, 8, 9, 10, 16, 17)

Retrocausation Where page 15 says retrocausation, the guide's chart says 'causes from the future'. (p. 15)

Superposition In this booklet, being in several states at once. The guide uses the word without spelling it out. (pp. 2, 8, 16, 17)

Unitary evolution The ordinary law: a smooth, reversible change that never picks a single result by itself. (p. 4)

Value state In modal interpretations, the extra part of the state that selects which properties are actually definite. (p. 9)

Wavefunction Quantum theory's mathematical description, also called the quantum state. (pp. 2, 3, then throughout)

Words the guide uses without explaining

With no other source, this booklet cannot explain them either. Look them up, or ask someone!

apparatus 7, 9, 12 · **Bell's theorem** 18 · **cellular automaton** 18 · **classical** 12 · **closed system** 13 · **complementarity** 12 · **deterministic** 18 · **equilibrium** 7 · **fine-tuning** 18 · **flashes** 8, 22 · **formalism** 12, 22 · **interfere** 13 · **local** 18, 22 · **loopholes** 18 · **matter density** 8, 22 · **no-go theorems** 14 · **non-separability** 22 · **ontology** 22 · **parameter-free** 16 · **quantum field theory** 15, 18, 22 · **quantum gravity** 22 · **quantum holism** 22 · **relativity** 9, 16 · **slicing of time** 7, 15 · **spacetime** 4, 8, 15, 16, 22 · **state space** 18 · **statistical independence** 18 · **time-symmetric** 15 · **velocity** 7 · **view-from-nowhere** 12



The Quantum Coin Puzzle

Quantum theory's usual equations allow a thing to be in several states at once. For our pretend quantum coin, that means 'heads and tails together'. Yet when we look, we always find just **one**.

How does that one definite result appear? And what is the wavefunction saying about the world?

INSIDE

- 13 families of answers, from Many worlds to Superdeterminism
- For each family: a picture of the coin, the big idea and the price it pays
- Four big questions to ask of every family
- Two charts for spotting patterns, and a word bank



No winner is marked. The thinking is up to you.



DAMIAN POPOLO

The Aeon Paradox

From Damian Popolo, author of *The Aeon Paradox*.

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